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Diurnal Oxygen Consumption and Rectal Temperature of Man During Continuous Cold Exposure

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ABSTRACT

IAMPIETRO, P. F., D. E. BASS AND E. R. BUSKIRK. (QM Research and Development Ctr., Natick, Mass.) *Diurnal oxygen consumption and rectal temperature of man during continuous cold exposure.* J. Appl. Physiol. 10(3): 398-400. 1957.—Effects of continuous cold stress on daily patterns of oxygen consumption ($\dot{V}O_2$) and rectal temperature were studied in five men. Cold stress consisted in living continuously in a chamber at 60°F for 14 days, wearing only shorts and with minimal physical activity. Resting $\dot{V}O_2$ and rectal temperatures were measured at 8 A.M., 12 M., 4 P.M. and 8 P.M. The cold period was preceded and followed by 2 weeks at 80°F. Activity and dietary composition were the same for all periods. Resting $\dot{V}O_2$ during warm periods exhibited gradual and characteristic increases during the day. This pattern was also found during cold exposure, but at a higher level; $\dot{V}O_2$ in the cold was 20% higher at 8 A.M., 16% at 12 M., 16% at 4 P.M. and 11% higher at 8 P.M. than at corresponding hours during control periods. Basal metabolic rate did not change throughout the experiment. Rectal temperatures at noon, 4 P.M. and 8 P.M. throughout the cold period did not differ from those at 80°F. Rectal temperatures at 8 A.M. were significantly higher in the cold than at 80°F. The results indicate that rectal temperature was well maintained during cold exposure and oxygen consumption appeared to respond in such a fashion as to subserve this maintenance.

RESTING oxygen consumption ($\dot{V}O_2$) has been shown to exhibit a characteristic rise during the day, which is not appreciably altered by living in various climates, e.g. desert, temperate, subarctic (1). In the temperate and hot climates the bodies of the men studied by these workers were no doubt exposed to ambient conditions, but in the subarctic this was probably not the case for the following reasons: a) the test subjects were well clothed and active while outdoors and probably were not cold, despite an average outdoor temperature of -23°F; b) resting oxygen consumption was measured indoors at a comfortable ambient temperature.

The present study was designed to evaluate the impact of cold stress per se on the diurnal pattern of $\dot{V}O_2$. Rectal temperatures (T_r), basal metabolic rate (BMR) and $\dot{V}O_2$ were measured in men who were exposed con-

tinuously to cold (uncomplicated by clothing and exercise) for 2 weeks.

METHODS

Five men lived in a room at 60°F for 2 weeks, without clothing except for cotton shorts, and were allowed only minimal activity (playing cards, reading, writing, watching television or movies, etc.). The 2 weeks at 60°F were preceded and followed by periods of 2 weeks, each at 80°F. During the cold period, each subject was allowed one woolen Army blanket at night. Activity and dietary composition were the same for all periods.

Oxygen consumption and rectal temperature were measured four times daily as follows: 0800 hours (8 A.M.) (prebreakfast), 1200 hours (noon) (prelunch), 1600 hours (4 P.M.) (presupper), and 2000 hours (8 P.M.). Oxygen consumption was measured with the Sanborn Waterless Metabolator; several practice trials were run on each subject to minimize training effects. Thirty minutes or more of bed rest (supine position) preceded each measurement and duplicate runs were routinely made on each man. Rectal temperatures were measured with calibrated clinical thermometers.

When BMR was measured during the cold period, the men were taken to a warm room (80°F) and given

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O₂ CONSUMPTION AND RECTAL TEMPERATURE IN THE COLD

399

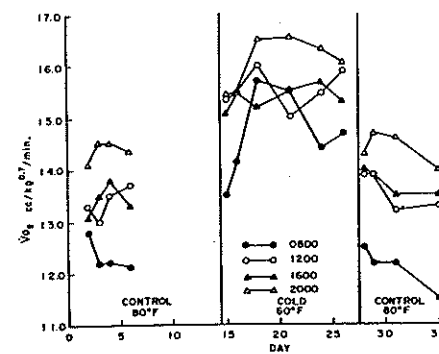


FIG. 1. Resting oxygen consumptions ($\dot{V}O_2$) are shown on a daily basis.

a blanket for covering. After approximately 1 hour in the warm room, the BMR was measured, following which the subjects were returned to the cold room.

RESULTS

Resting oxygen consumptions ($\dot{V}O_2$) are shown on a daily basis in figure 1. $\dot{V}O_2$ was appreciably higher during the cold period than during the control (precold) period, and the values quickly returned to control levels after the cold exposure was terminated. Although $\dot{V}O_2$ during the first 2 days in the cold was lower than measured on subsequent cold days, this was probably due to the fact that the temperature of the chamber was 64°F (refrigeration equipment difficulties) during these 2 days as compared with 60°F for the remaining days. Disregarding these first 2 days, there appeared to be no trend in $\dot{V}O_2$ as cold exposure continued (fig. 1).

The effect of cold exposure on the diurnal pattern of $\dot{V}O_2$ is shown in figure 2. Each point represents the mean for each time of day by periods; all the days of each period were included in computing the averages. A diurnal pattern of gradually increasing $\dot{V}O_2$ during the day was found during the control period. The same pattern was observed in the cold, but at a higher level. Thus, during the control period $\dot{V}O_2$ ranged from 12.3 to 14.4 cc/kg^{0.7}/min. at 0800 and 2000 hours, respectively; the range during the cold, on the other hand, was 14.6 to 16.1 cc/kg^{0.7}/min.¹ During the 're-

¹ We have routinely used body weight as a unit of reference, since weight loss has been common to most

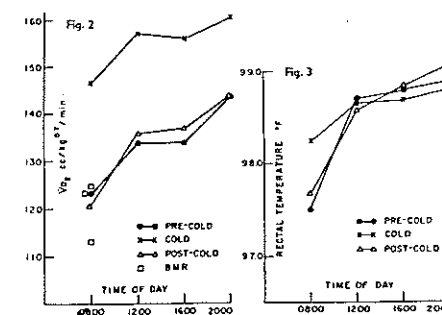


FIG. 2. Effect is shown of cold exposure on the diurnal pattern of $\dot{V}O_2$.

FIG. 3. Shows rectal temperatures measured at the same time as $\dot{V}O_2$.

covery' (postcold) period, the diurnal pattern was almost identical to controls (fig. 2). Although the absolute values in the cold were higher than at corresponding hours of the control and recovery periods, the range (0800-2000 hr.) was smaller in the cold than in the warm periods. Basal metabolic rates during the cold period were not significantly different from controls (fig. 2). This is in agreement with the findings of Fainer *et al.* (2).

Rectal temperatures (T_r) measured at the same time as $\dot{V}O_2$ are shown in figure 3. The well-known diurnal increase in T_r was observed during the control and recovery periods. The diurnal pattern was modified during the cold period in that there was a flattening of the slope. This was due to the fact that the T_r at 0800 hours was significantly higher in the cold than in the control period, with no significant differences between the two periods at other times of day. This will be discussed in the following section.

DISCUSSION

The picture presented by our data is one of a well-maintained rectal temperature during the cold period, accompanied by appreciable increases in heat production. The increased $\dot{V}O_2$ was probably in large measure the result

of our experiments. When body weight is lost, surface area may not change in proportion and therefore may not be an accurate reference unit under these conditions. The exponent used varies from author to author, and usually ranges between 0.5 and 0.9.

of increased muscle activity, e.g. nondetectable shivering (3).

The higher-than-control rectal temperatures at 0800 hours in the cold merit some consideration. In this connection, it is noteworthy that $\dot{V}O_2$ followed the pattern of rectal temperatures at 0800 hours in that it, too, showed an increment which was relatively greater than at other times of day as compared to controls; the increment was 2.3 cc/kg^{0.7}/min. at 0800, and 1.7 cc/kg^{0.7}/min. at 2000 hours. Thus, the greatest increase in heat production in the cold occurred at the only time of day (0800) at which measured rectal temperature was significantly higher than controls.

We have here studied two parameters associated with temperature homeostasis in a situation which imposed a strain on thermoregulation. One of these—rectal temperature—was well maintained; the other— $\dot{V}O_2$ —responded in a way that appeared to subserve

this maintenance. It is of interest that none of the responses reported here showed adaptations interpretable as acclimatization to cold. If cold acclimatization occurred, evidence must be sought for in adaptations of other responses. Such evidence was forthcoming from another aspect of this study in connection with measurements of venous distensibility (4).

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